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THE PALPI OF MALE SPIDERS.

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INTRODUCTION.

The remarkable modification of the palpi of the males of spiders into organs for the transference of the seminal fluid to the female at the time of pairing of the sexes attracted the attention of naturalists at a very early date; and the great variety of forms presented by these organs has led systematists to make much use of them in taxonomic work. In practically all of the more important works on the classification of spiders there are figures and descriptions of the palpi of males.

Notwithstanding the general recognition of the value of these organs for taxonomic purposes our knowledge of their structure is very inadequate. Several important contributions to this subject have been published and are well known, notably those of Westring ('61), Menge ('66), Bertkau ('75 and '78), Wagner ('87), Van Hasselt ('89), and Chamberlin ('04 and '08). Still we find, even in the more recent publications, figures of palpi given with almost no effort to identify their parts; and even when some of the parts are named we find different terms applied to homologous parts in the descriptions of different genera.

The necessity of selecting from the many terms that have been proposed for parts of the palpi, a set to be used in a handbook of North American Spiders that the writer has in preparation, and the need of terms for parts that have not been described, has led to the preparation of this paper. It is hoped that the publication of it may tend to bring about a greater uniformity in nomenclature and an increased use in systematic works of the extremely valuable characters presented by these organs.

THE MORE GENERALIZED TYPES OF PALPI.

In all spiders the external opening of the reproductive organs of the male is on the lower side of the abdomen near its base, in the epigastric furrow. Some time before pairing the seminal fluid is emitted from this opening and is stored in a tubular cavity in an appendage of the last segment of the palpus, where it is retained until the pairing of the sexes, and from which it then passes to the spermathecae of the female. As the object of this paper is purely morphological the details of this transference of the sperm will not be discussed here; the reader is referred to the recently published papers by Montgomery ('03 and '10) for a review of the subject and for an account of original observations.



FIG. 1. Tarsus of *Filistata hibernalis*: 1, lateral aspect; 2, oblique view; 3, mesal aspect.

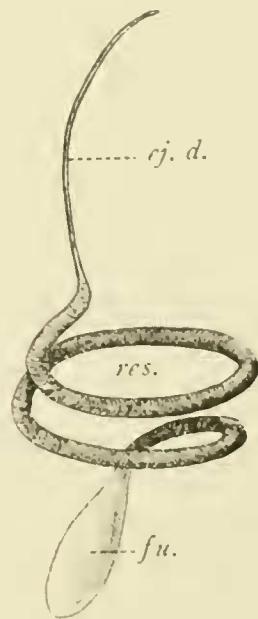


FIG. 2. Diagram of the receptaculum seminis.

The genital appendage of the palpus of the male is exceedingly complicated in structure in the more specialized spiders, as in the Argiopidae; but it is comparatively simple in some of the more generalized families. A few illustrations of the simpler forms will be given here.

THE FILISTATA TYPE OF PALPUS.—In *Filistata hibernalis*, which is a very common house spider in the South, is found the most simple type of male palpus that I have seen among spi-

ders. In the males of this species, the distal end of the last segment of the palpus, the tarsus, contains a coiled tube (Fig. 1); this is the *receptaculum seminis* (Wagner '87). The proximal portion of this tube is slightly enlarged and ends blindly; the distal part is slender and extends through a slender, twisted prolongation of the tarsus ending at its tip by an open mouth. The modified terminal portion of the tarsus, which contains the receptaculum seminis, is the *genital bulb*. By looking directly at the tip of the palpus, instead of at one side of it, it can be seen that the base of the bulb is situated in a cavity in the end of the main part of the palpus (Fig. 1, *a.*). This cavity is the *alveolus* (Menge '66). The slender prolongation of the bulb, which contains the terminal portion of the receptaculum seminis is the *embolus* (Menge '66; *style*, Simon, '92). Excepting the specialization of the distal end of the tarsus, the segments of the palpus of *Filistata* resemble quite closely the corresponding segments of a leg, the relative length of the femur, patella, and tibia being quite similar; there is not the shortening of the tibia, which is so marked in many of the specialized forms, as in *Aranea* for example.

A study of the palpus of *Filistata* gives a clue to the probable course of the evolution of the genital bulb. It is evident that the bulb is a specialization of the tip of the tarsus, and its most striking feature is the presence within it of the coiled receptaculum seminis. Regarding the origin of the receptaculum seminis, the fact that it is furnished with a transversely striated intima, like the intima of a trachea, indicates that it is merely an invagination of the body-wall. In its primitive form, it was probably a cuplike depression in the tip of the tarsus.

In its most perfect form, as seen in the more specialized spiders, the receptaculum seminis consists of three quite distinct parts: first, the proximal end of it, the *fundus*, is enlarged so as to form a pouch, the wall of which is more delicate than that of the other parts (Fig. 2, *fu.*); I have not been able to see tænidia in the intima of this part, and infer that it serves as a compressible bulb; second, the intermediate portion, the *reservoir*, is a large coiled tube occupying the middle division of the genital bulb (Fig. 2, *res.*), in this part the tænidia of the intima are well-developed and are sometimes very prominent; third, the terminal portion constitutes the *ejaculatory duct*; this is the slender tube traversing the apical division of the bulb (Fig. 2,

ej. d.); the wall of this duct is often dark in color, which renders it easy to trace the course of the duct in an expanded bulb.

The tracing of the course of the ejaculatory duct is often the only method by which the embolus can be recognized in a complicated palpus; for when the embolus is small or when it is lamelliform a slender apophysis may be mistaken for it. Even Menge ('66), who proposed the term embolus for this part labels the terminal apophysis as embolus in several of his figures of *Epeira*.

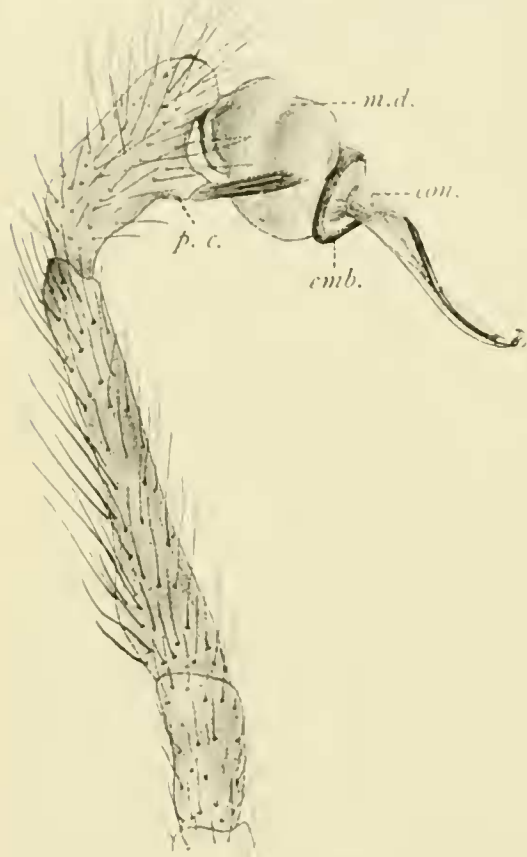


FIG. 3. Palpus of *Hypochilus thorelli*.

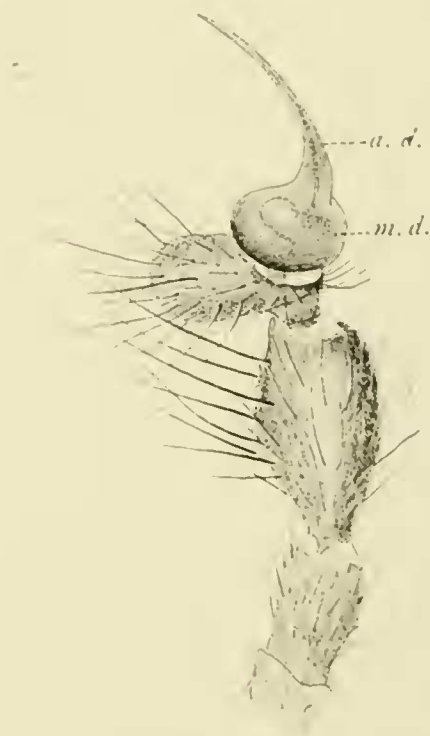


FIG. 4. Palpus of *Loxosceles rufescens*.

There is no reason to believe that the lumen of the receptaculum seminis communicates with the body cavity; the *meati sanguinis* described by Wagner ('87) do not exist.

After the stage represented by *Filistata* had been reached, a shifting in the position of the bulb occurred in most spiders. Instead of occupying a terminal position, at the tip of the tarsus, it has moved to one side of the tarsus in all spiders known to me except *Filistata*. In the tarantulas and in *Hypochilus thorelli*, the most generalized in many respects of the true spiders,

the genital bulb is nearly terminal but is, nevertheless, distinctly on one side of the tarsus (Fig. 3). In other spiders it has moved to a greater or less extent towards the base of the tarsus, which it has nearly reached in many, as for example in *Loxosceles rufescens* (Fig. 4). It has been suggested by Nelson ('09) that this shifting of the position of the bulb is for the protection of it from mechanical injury.

In *Hypochilus* (Fig. 3) and in *Loxosceles* (Fig. 4), the alveolus is comparatively small; but in many spiders it is large, resulting in the tarsus being more or less cuplike in form; this is shown in some of the figures of the more specialized palpi given later. This cuplike form of the tarsus as distinguished from its appendage, the genital bulb, suggested for it the name *cymbium* (Menge '66), which is the classical name of a small drinking vessel. The term *lamina*, proposed by Westring ('61) antedates *cymbium*; but I have adopted the later term, as it is the one in general use.

The well-known fact that tarsal claws do not exist on the palpi of male spiders is easily understood if we regard the genital bulb as a specialization of the tip of the palpus, as is indicated by the structure of the palpus of *Filistata* described above. Sometimes, as in *Lycosa*, the tip of the *cymbium* bears one, two, or three stout spines; these have been regarded as "transformed claws" (Chamberlin '08); it seems more probable for the reason given above, that these are secondarily developed structures instead of vestigial claws; in fact there are frequently strong spines distributed over the surface of the *cymbium*.

The genital bulb in *Filistata* is helicoid; this is due, so far as the larger basal part is concerned, to the fact that the wall of it is molded over the coiled receptaculum seminis; but the twisting of the bulb is continued to the tip of the embolus, although in this part, the receptaculum seminis is not coiled but extends in a nearly direct line. I know of no other case where the helicoid form of the genital bulb is so well-marked as here; but there is always a more or less spiral arrangement of parts.

THE TARANTULA TYPE OF PALPUS.—In those spiders that are commonly known in this country as tarantulas, and which represent the more generalized of the two principal divisions of the order Araneida, there exists a comparatively simple type of

palpus; but in none of them that I have seen, or of which I have seen figures, is it as generalized as is the palpus of *Filistata*.

In the palpi of the tarantulas, the genital bulb has migrated to one side of the tarsus; but it is still near the tip of this segment of the palpus (Fig. 5). A striking feature of the bulb is that it is divided into two distinct segments. The smaller basal segment may be termed the basal division of the bulb (Fig. 5, *b. d.*). The larger segment consists of two parts: a large stout part, which may be termed the middle division of the bulb (Fig. 5, *m. d.*), and a slender terminal portion, which may be termed the apical division of the bulb (Fig. 5, *a. d.*); there is, however, no distinct line between the middle and the apical divisions, the one gradually merges into the other; but in the more specialized palpi these two divisions are distinctly separated.



FIG. 5. Tarsus of *Eurypelma*.

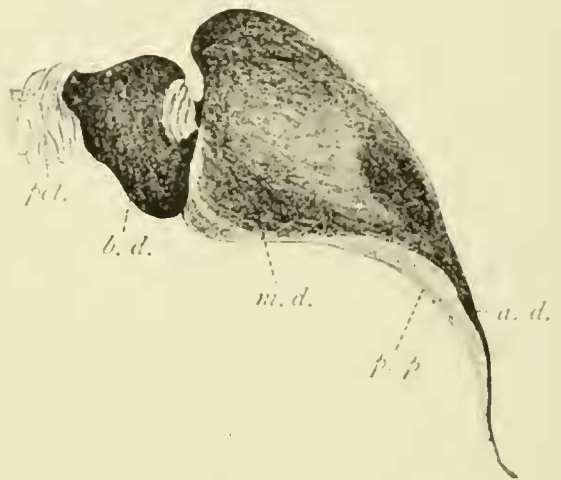


FIG. 6. Genital bulb of *Eurypelma californicum*.

In the articulating membrane which joins the bulb to the tarsus, there is on one side a distinct sclerite, which can be seen by removing the bulb from the alveolus (Fig. 6, *pet.*); this is doubtless homologous with what has been termed the *petiole* (Chamberlin '04) in more specialized palpi.

The greater part of the wall of the bulb in the tarantula type of palpus is very densely chitinized but there is a longitudinal area on the concave side of the middle and apical divisions which is comparatively soft (Fig. 6, *p. p.*); it may be that this part is distended by blood pressure at the time of pairing, as is the hæmatodocha in the more specialized palpi; but upon this point I have no data. This soft strip may correspond to that portion of the spiral type of embolus, described later, that I have designated the *pars pendula*.

THE PALPUS OF LOXOSCELES.—In certain genera of the true spiders, the palpi are as simple as in the tarantula type. In *Loxosceles* of the family Scytodidæ, for example (Fig. 4), although the bulb has migrated nearly to the base of the tarsus; the bulb itself is very simple in structure. The basal division of the bulb is inconspicuous; the middle division is nearly spherical, and the apical division is long and slender. Here the receptaculum seminis is differentiated into the three parts described above; the reservoir is large, while the ejaculatory duct is very slender.

THE PALPUS OF DYSDERA.—In the family Dysderidæ two quite distinct types of palpi occur. In *Ariadna* the palpus resembles very closely that of *Loxosceles*; but in *Dysdera* it is of a very different form (Fig. 7); this is due to the fact that the apical division of the bulb is not slender, and is sharply differentiated from the middle division, its wall being much less densely chitinized. But there is on each margin a distinct sclerite; and this part of the bulb bears distinct apophyses. At the tip of the apical division there appears to be the beginning of a separation into embolus and conductor.

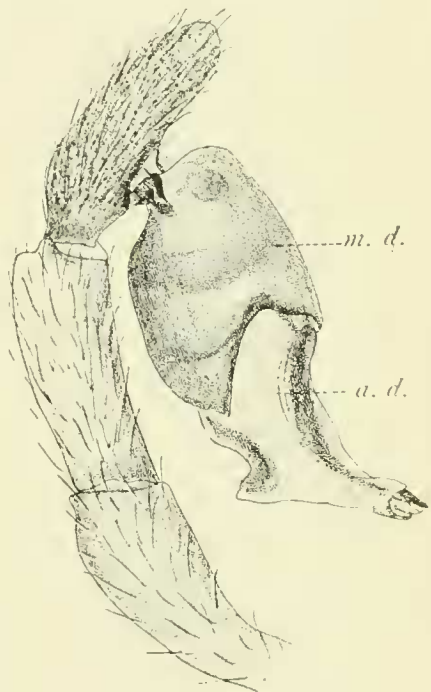


FIG. 7. Palpus of *Dysdera interrita*

A summary of the parts of the tarsus in the more generalized types of palpi of males is shown by the following table:

Body of tarsus or cymbium, containing the alveolus.

Genital bulb.

Internal parts.

Receptaculum seminis.

Fundus.

Reservoir.

Ejaculatory duct.

External parts.

Petiole.

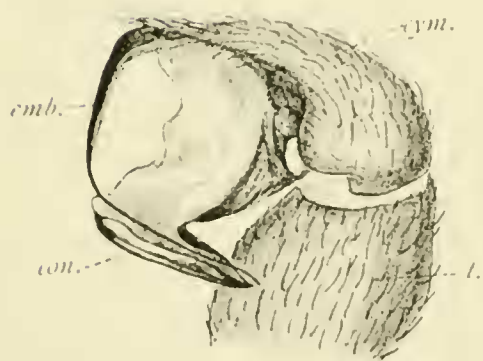
Basal division.

Middle division.

Apical division or embolus.

THE INTERMEDIATE TYPES OF PALPI.

There are palpi which hold an intermediate position as regards complexity of structure between the comparatively simple tarantula type and the exceedingly complex forms to be described later. These intermediate types occur in widely separated portions of the araneid series; but agree in their more essential characteristics; for sake of brevity, I will discuss only a few examples of the intermediate types; and will then pass to a description of forms in which the maximum number of parts is found.

FIG. 8. Tarsus of *Atypus bicolor*.FIG. 9. Genital bulb of *Pachygnatha*, extended.

The most important characteristic of these intermediate types is that the apical division of the bulb is separated into two, more or less nearly, parallel parts. One of these parts contains the ejaculatory duct of the receptaculum seminis, this is the *embolus* (Menge '66); the other is intimately associated with the embolus and is known as the *conductor of the embolus*, or the *conductor of the style*, or, simply, as the *conductor*.

A comparatively simple example of this group of palpi is that of *Atypus bicolor*. Here the terminal part of the con-

ductor is a broad concave plate (Fig. 8, *con.*), in which the terminal portion of the embolus rests.

A more complicated form of the apical division of the bulb exists in *Hypochilus thorelli* (Fig. 3). Here the embolus is coiled about the conductor, the terminal part of which is concave so as to support the terminal portion of the embolus; the tip of the conductor bears a delicate membranous flap.

In *Hypochilus* the tarsus bears a branch which supports a prominent bunch of bristles (Fig. 3, *p. c.*); this may be a rudimentary form of paracymbium, a part that is well developed in *Pachygnatha*.

A somewhat similar condition exists in *Pachygnatha* (Fig. 9). Here the proximal part of the embolus is coiled about the conductor, which is a broad twisted plate; and the terminal portion of the embolus is supported by the corresponding part of the conductor. When at rest the apical division of the bulb rests in the concave tip of the cymbium; but in the specimen figured the bulb has been extended so to show the parts better; and the embolus and conductor have been separated at the tip.

In *Pachygnatha* the tarsus is divided into two distinct parts, which are joined by a movable articulation at the base. The larger part is the cymbium (Fig. 9, *cym.*) the smaller part, the *paracymbium* (Menge '66) or the accessory branch of the tarsus (Simon '92) (Fig. 9, *p. c.*). The cymbium and the paracymbium resemble the other segments of the palpus in the nature of their cuticula and in the fact that they are clothed with hairs.

The term conductor is in general use and was substituted for the term *spermophorum* of Menge, which was suggested by a misconception of the function of this part. As to the particular part to which the term should be applied there is no doubt. Menge ('66, Plate 15) clearly indicates, in his figures of the palpus of *Tetragnatha extensa*, the part to which he applied the term spermophorum; and the term conductor must be applied to the homologous part whenever it is used. This, however, has not been done; in many descriptions an entirely different part has been termed the conductor, merely because it is more or less nearly parallel with the embolus. A discussion of the function of the conductor is given later.

THE MORE SPECIALIZED TYPES OF PALPI.

In the development of the bulb of the male palpus in the more specialized families of spiders there has been evolved an exceedingly complicated organ, which is difficult to understand, on account of its small size and the fact that when at rest it is compactly folded. Fortunately when such a palpus is boiled in a solution of caustic potash (10%) the bulb expands so that its parts can be seen; and if preserved in glycerine, it remains flexible, so that it can be easily manipulated. The expanded bulbs figured below were prepared in this way. Even with the best of preparations, it is sometimes difficult to make out the relation of parts; this can be most easily accomplished by the use of a stereoscopic binocular microscope.

The extreme specialization of the palpi of males is marked chiefly by the development of hæmatodocha, to be described later, and by an increase in the number of distinct parts and appendages of the bulb. The maximum degree of specialization is to be found in the Araneinæ, of which the palpi of several species of *Aranea* are described later. The understanding of the relation of the parts of the bulb in this genus will be facilitated by a study first of a more simple form, such as is found in the Linyphiidæ.

THE LINYPHIA TYPE OF PALPUS.—The very common *Linyphia phrygiana* will serve as an example of the Linyphiidæ.

As in *Pachygnatha*, just described, the body of the tarsus of *Linyphia* consists of two parts; the *cymbium* (Fig. 10, *cym.*), and the *paracymbium* (Fig. 10, *p. c.*). The *alveolus* is a circular cavity near the base of the cymbium.

When the bulb is expanded, the three divisions of it are distinctly separated, there being a slender neck between the basal division (Fig. 10, *b. d.*) and the middle division (Fig. 10, *m. d.*), and also a similar slender neck between the middle division and the apical division (Fig. 10, *a. d.*).

The wall of the basal division of the bulb consists of two parts; the basal hæmatodocha, and the subtegulum.

The basal hæmatodocha.—The genital bulb is attached to the cymbium, within the alveolus, by means of a saclike structure, which, ordinarily, is inconspicuous or completely concealed by other parts of the bulb, but which is very conspicuous in the expanded bulb (Fig. 10, *b. h.*). This has been named the

hæmatodocha from the fact that at the time of pairing it is distended with blood (Wagner '97). The wall of the hæmatodocha appears to consist of elastic connective tissue; hence the name *spiral muscle* applied to it by Menge is inappropriate. In fact no muscle tissue has been found within the genital bulb. As similar extensible blood-sacs are present in more distal parts of the bulb of many spiders, I suggest that this one be termed the *basal hæmatodocha*.



FIG. 10. Expanded bulb of *Linyphia phrygiana*.

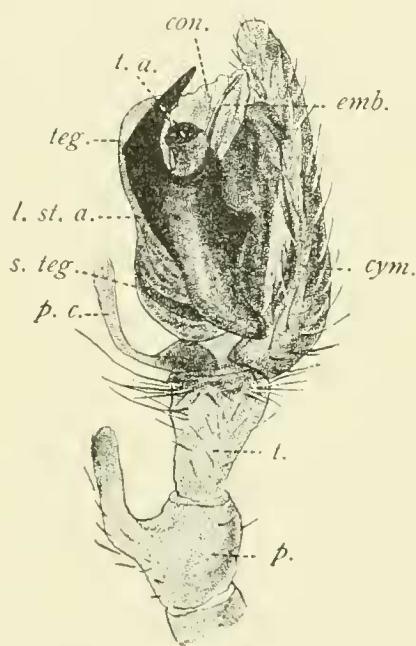


FIG. 11. Palpus of *Linyphia phrygiana*.

The subtegulum.—The proximal end of the basal hæmatodocha is attached to the cymbium, the distal end, to a ringlike sclerite, for which I propose the term *subtegulum* (Fig. 10, *s. teg.*). The existence of a sclerite in this position was indicated by Wagner, and it is lettered in his figures *s. teg.*, but its ringlike form has not been described; in fact, Wagner states that the hæmatodocha ends in the tegulum.

The middle division of the bulb.—The middle division of the bulb (Fig. 10, *m. d.*) is that part which contains the chief portion of the receptaculum seminis, the *reservoir*; its wall is the tegulum, and it bears an appendage, the median apophysis.

The tegulum.—The term tegulum was applied by Wagner to all of the more densely chitinized parts of the wall of the genital bulb; but as it is desirable that the different sclerites should

bear distinctive names, I propose that this term be restricted to the sclerite that forms the wall of the middle division of the bulb. In *Linyphia*, the tegulum, in this restricted sense is a ringlike sclerite (Fig. 10, *teg.*).

The median apophysis.—Arising within the distal margin of the tegulum there is an appendage, only the tip of which is shown in the view of the bulb figured here (Fig. 10, *m. a.*); this is the *median apophysis*. In many spiders this appendage is very conspicuous; and to it have been applied several names. In fact in several instances a writer has applied different names to this part in his descriptions of different genera. Among the names that have been applied to it are *lamella characteristica* and *apophysis mediana* (Chyzer et Kulezynski '91), *clavis* and *unca* (F. O. Pickard-Cambridge '97-'05), and *scopus* (Chamberlin '04). The term median apophysis occurs frequently in descriptions, and is the older name for this part.

The median apophysis is articulated to the middle division of the bulb near the point from which the apical division arises; and in some cases, as in *Aranca*, it appears to be more closely articulated with a basal segment of the apical division, the radix, than it is with the tegulum.

The apical division of the bulb.—This division includes that portion of the bulb which lies distad of the middle division; it consists of two subdivisions: the conductor and the embolic subdivision. The embolic subdivision is traversed by the ejaculatory duct and is composed of several distinct parts. In fact the multiplication of parts of the embolic subdivision is the most characteristic feature of the more specialized types of palpi as contrasted with the intermediate types described above.

The conductor.—The conductor (Fig. 10, *con.*) is easily recognized by its relation to the embolus, which rests upon it, and by its membranous texture. Its attachment to the middle division of the bulb is by means of an exceedingly delicate membrane.

In *Linyphia* the embolus rests upon the conductor throughout its length; but in many genera the palpi of some of which are described later, the function of the conductor is evidently to protect the tip of the embolus in the unexpanded bulb. In many cases the embolus is very long while the conductor is short; but in every case the embolus in the unexpanded bulb occupies such a position that its tip is protected by the conductor.

In most cases the conductor can be recognized at a glance by its peculiar texture; sometimes it is chitinized to a considerable extent, but even then it usually has a membranous margin; and in any case it can be recognized by its relation to the tip of the embolus in the unexpanded bulb.

The embolic subdivision.—Closely connected with the membranous base of the conductor is the base of a separate subdivision of the apical division of the bulb; as this portion bears the embolus it may be termed the *embolic subdivision*.

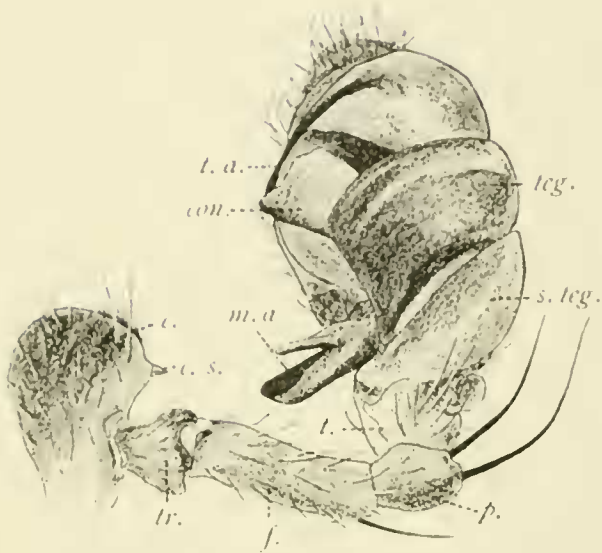
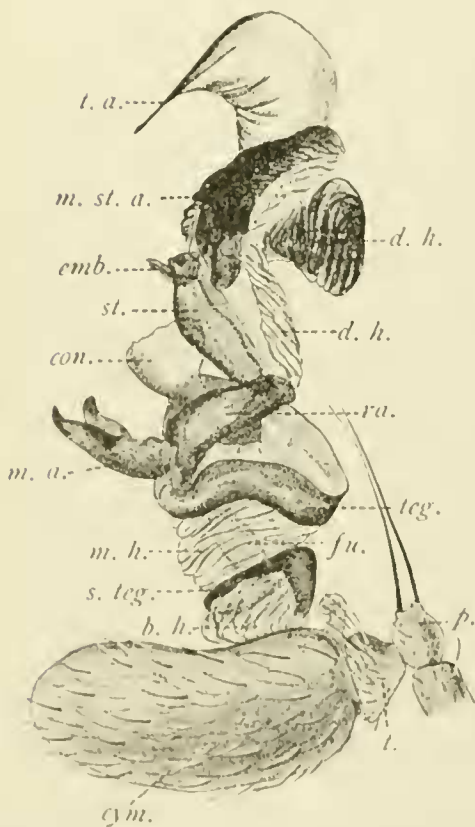
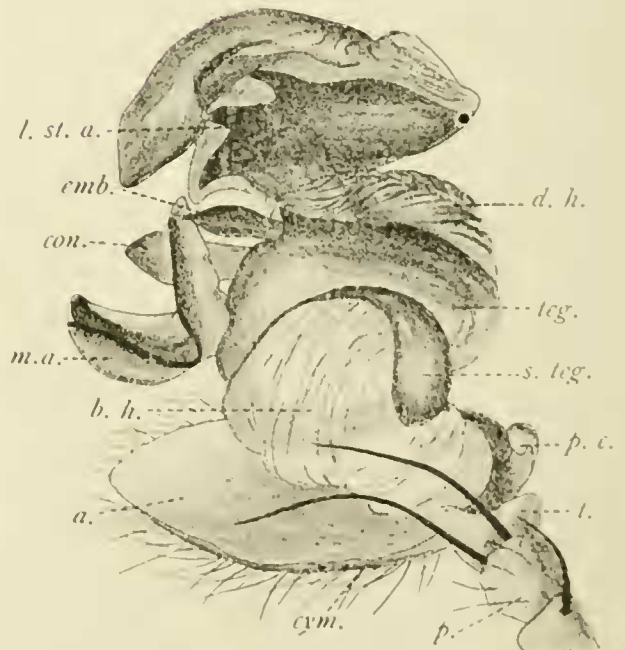
The radix and the stipes.—Immediately following the membranous neck that connects the middle and the apical divisions of the bulb and parallel with the membranous base of the conductor, there are two segments of the embolic subdivision; to the basal one of these I apply the term *radix* (Fig. 10, *ra.*); and to the second, the term *stipes* (Fig. 10, *st.*). For a more distinctly segmented condition of the base of the embolic subdivision see the figures of *Aranea circulata* given later (Fig. 18 and 19), where the corresponding parts bear the same letters.

The embolus.—The organ through which the ejaculatory duct opens, the *embolus*, is comparatively simple in *Linyphia*, being a short spinelike part (Fig. 10, *emb.*).

The lateral subterminal apophysis.—In *Linyphia phrygiana* there is developed a remarkable platelike apophysis, which serves to protect the exposed face of the unexpanded bulb. In Figure 10 (*l. st. a.*), only the edge of this apophysis is shown; but in Figure 11, the broader face of it is represented. I designate this the *lateral subterminal apophysis* as it occurs on the lateral aspect of the unexpanded bulb, and also to distinguish it from an apophysis developed on the opposite face of the bulb in a subterminal position, which occurs in certain other genera.

The terminal apophysis.—The embolic subdivision ends in a strongly chitinized lobe, which may be designated the *terminal apophysis* (Fig. 10, *t. a.*). To apophyses of this kind Menge applied the term *retinacula*; but as this term predicates their function, which in some cases is obviously not that implied by the name, I prefer apophysis with a modifying term indicating the position of the particular apophysis described.

THE ARANEA TYPE OF PALPUS.—I have selected the palpus of *Aranea frondosa* (*Epeira strix*) as an example of an extremely specialized palpus. In Figure 12 the entire palpus, with the bulb unexpanded, is represented slightly twisted so as to show

FIG. 12. Palpus of *Aranea frondosa*.FIG. 13. Lateral aspect of an expanded bulb of *Aranea frondosa*.FIG. 14. Mesal aspect of an expanded bulb of *Aranea frondosa*.FIG. 15. Lateral aspect of an expanded bulb of *Aranea ocellata*.

the ventral aspect of the proximal segments and the lateral aspect of the bulb.

The proximal segments of the palpus.—This account of the palpi of male spiders is devoted almost entirely to a discussion of the parts of the tarsus, the proximal segments being well-understood; there are, however, a few features of these segments in the aranea type that merit attention here.

Upon the coxa there is a prominent spur, *the coxal spur* (Fig. 12, *c. s.*); and upon the inner side of the femur near its base, there is a groove, the *femoral groove*, into which the coxal spur fits when the palpus is extended forward. The presence or absence of this spur and groove is an important generic characteristic in the Araneinæ.

The patella bears two prominent spines at its apex (Fig. 12, *p.*). This is also true in the males of several other genera; but in the greater number of genera of the Araneinæ there is only a single spine in this position.

The most striking feature of the tibia is its shortness, being of about the same length as the patella.

The tarsus.—As in *Linyphia*, the tarsus of *Aranea* consists of two parts; the cymbium and the paracymbium. But in *Aranea* the paracymbium (Fig. 13, *p. c.*) is merely a prominent apophysis arising from the base of the cymbium and is not articulated with the cymbium by a movable joint as in *Linyphia* and in *Pachygnatha*. The alveolus is much more extended than it is in *Linyphia*; here it occupies nearly the whole length of the cymbium (Fig. 13, *a.*).

The unexpanded bulb.—In the unexpanded bulb of *Aranea frondosa*, the subtegulum (Fig. 12, *s. teg.*), tegulum (Fig. 12, *teg.*), and a terminal lobe of the apical division of the bulb, bearing a long and slender terminal apophysis (Fig. 12, *t. a.*) are visible. Two prominent appendages can also be seen; the median apophysis (Fig. 12, *m. a.*) and the conductor (Fig. 12, *con.*).

The expanded bulb.—Two figures of the expanded bulb are given here; Figure 13 represents the lateral aspect of the bulb, the aspect that is exposed when the bulb is not expanded; and Figure 14, the mesal aspect, the one that is next the cymbium in the unexpanded bulb.

The basal hæmatodocha is essentially the same as in *Linyphia* (Fig. 13 and 14, *b. h.*).

The subtegulum is a ringlike sclerite but its form is like that of a seal-ring being narrow on the mesal aspect of the bulb and wide on the lateral aspect (Fig. 14, *s. teg.*). This wider part of the subtegulum is all of it that is commonly observed and has been termed the *lunate plate* (Chamberlin '04).

The specimen represented in Figure 14 was more fully expanded than that used for Figure 13. In the more expanded specimen there is evident a large hæmatodocha between the subtegulum and the tegulum; this I designate the *middle hæmatodocha* (Fig. 14, *m. h.*). The dark axial object seen through the wall of the middle hæmatodocha is the fundus of the receptaculum seminis (Fig. 14, *fu.*).

The tegulum is also a ringlike sclerite, which is broad on the lateral aspect of the bulb (Fig. 13, *teg.*), and is narrow on the mesal aspect (Fig. 14, *teg.*).

The median apophysis (Figs. 12 and 13, *m. a.*) is a conspicuous appendage, which projects from the ventral side of the bulb. Although the position of this appendage in *Linyphia*, in which the middle and apical divisions of the bulb are distinctly separated, shows that the median apophysis is an appendage of the middle division, in *Aranea* it appears to be articulated with the base of a proximal segment of the apical division, the radix.

The conductor (Fig. 14, *con.*) arises at the base of the apical division and is closely connected with the tegulum.

The radix (Fig. 14, *ra.*) is much larger than in *Linyphia*. Here it forms the wall of one side of the basal segment of the embolic subdivision of the apical division. That this is the case is more clearly shown in the bulb of *Aranea circulata* (Fig. 18 and 19, *ra.*), where the segmentation of the embolic subdivision is much more marked.

The stipes (Fig. 14, *st.*) is also much larger than in *Linyphia*; it is articulated with the distal end of the radix. Like the radix, the stipes forms the walls of one side of a segment of the embolic subdivision of the bulb, a fact which is also well shown in the bulb of *Aranea circulata* (Fig. 18 and 19, *st.*).

The embolus is borne by the embolic subdivision distad of the stipes; it projects ventrad between the distal end of the stipes which is mesad of it, and the conductor, which is laterad of it in the unexpanded bulb. In the specimen represented in Figure 14, the distal end of the stipes and the embolus have been pushed away from the conductor in the expanding of the bulb.

The distal hæmatodocha.—The most striking feature of the embolic subdivision in the aranea-type is the presence of a large hæmatodocha, which when expanded over-shadows all other parts. This hæmatodocha I designate the *distal hæmatodocha* (Fig. 13 and 14, *d. h.*). It is doubtless due to the development of this hæmatodocha that the radix and the stipes are restricted to one face of their respective segments of the apical division in *Aranea frondosa*, the remaining parts of the wall of these segments forming a part of the distal hæmatodocha.

The mesal subterminal apophysis.—On the mesal aspect of the bulb, there arises from the distal hæmatodocha a prominent apophysis (Fig. 14, *m. st. a.*); this may be termed the *mesal subterminal apophysis*.

The lateral subterminal apophysis.—On the lateral aspect there is also an apophysis borne by the distal hæmatodocha (Fig. 13, *l. st. a.*); this may be termed the *lateral subterminal apophysis*.

The terminal apophysis.—In *Aranea frondosa*, the tip of the embolic subdivision of the bulb ends in a spear-shaped apophysis (Fig. 13, *t. a.*); this may be termed the *terminal apophysis*.

THE PALPUS OF ARANEA OCELLATA.—A glance at the palpus of *Aranea ocellata* (*Epeira patigiata*) will show that it is of essentially the same type as that of *Aranea frondosa* but is different in some details. It is figured here to illustrate the kind of variations in form that serve to distinguish closely allied species (Fig. 15.) The median apophysis differs markedly in form from that of *A. frondosa*; the tegulum bears a small but distinct apophysis; the lateral subterminal apophysis bears two prominent teeth; and the terminal apophysis is lacking, the embolic subdivision ending in a blunt lobe.

THE PALPUS OF ARANEA CIRCULATA.—The most striking modification of the aranea type of palpus, taking the palpus of *Aranea frondosa* as typical, is that of *Aranea circulata*, which is the most complex palpus that I have studied. In the unexpanded bulb, there appears to be no resemblance to the bulb of *Aranea frondosa*. In *Aranea circulata* (Fig. 16 and 17), the bulb is very large and the cymbium comparatively small and narrow (Fig. 17, *cym.*). The basal hæmatodocha (Fig. 16, *b. h.*) is conspicuous, which is the result of the other parts of the bulb being twisted into unusual positions. The median apophysis is large and projects beyond the tip of the bulb (Fig. 16, *m. a.*).

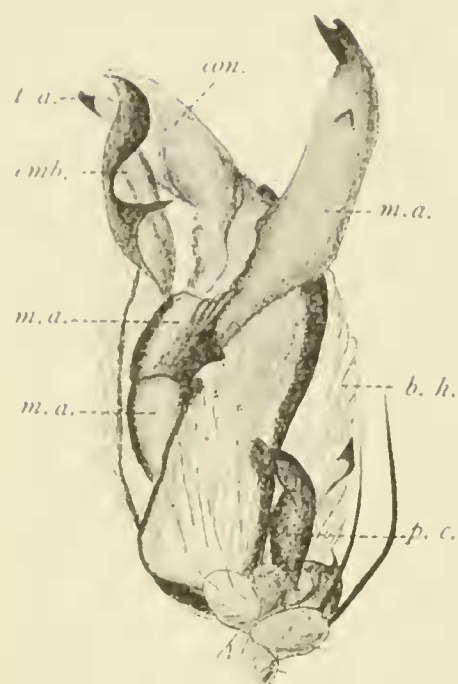


FIG. 16. Unexpanded bulb of *Aranea circulata*.

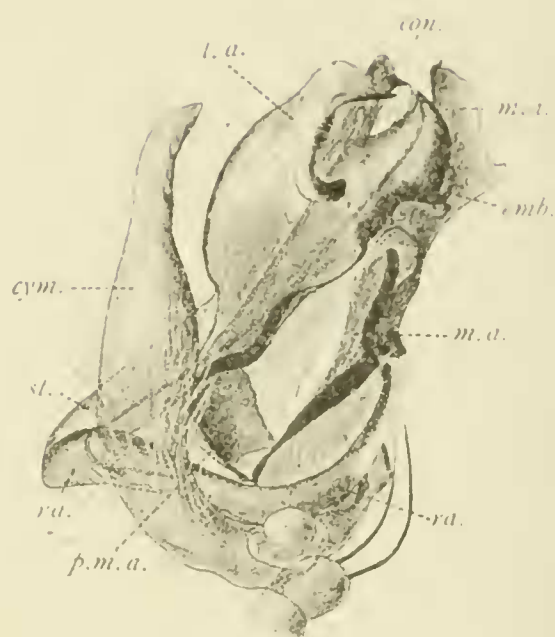


FIG. 17. Unexpanded bulb of *Aranea circulata*.

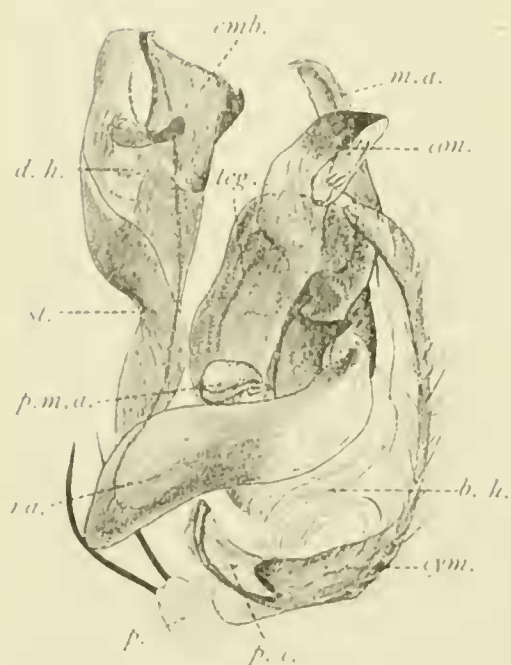


FIG. 18. Expanded bulb of *Aranea circulata*.

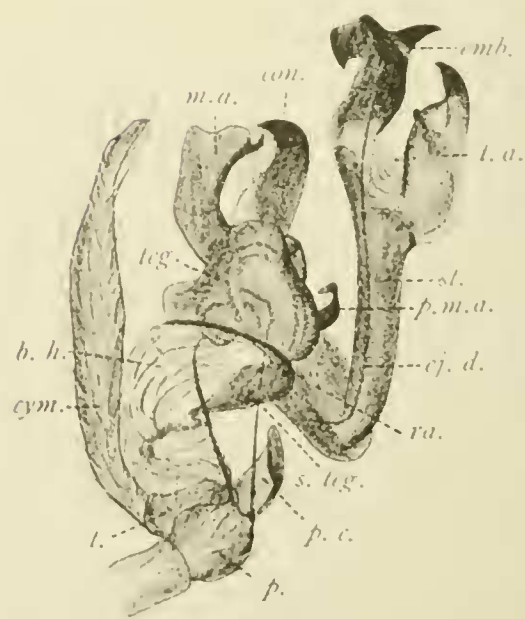


FIG. 19. Expanded bulb of *Aranea circulata*.

But the most remarkable feature is an elbowed structure on the mesal aspect at the base of the bulb (Fig. 17). The fact that the ejaculatory duct can be traced throughout the length of this elbowed structure gave the first definite clew to the relations of the parts of the bulb. The part containing the ejaculatory duct evidently pertains to the apical division of the bulb, although it appears to arise from the base of the bulb.

When the bulb of *Aranea circulata* is expanded and untwisted, as occurs in the process of expansion, the relation of the parts is more easily seen. Figures 18 and 19 represent two views of a preparation of this kind. If Figure 19 be studied it will be seen that the relations of parts are essentially the same as in *Aranea frondosa* (Fig. 14); the basal hæmatodocha, subtegulum, and tegulum follow in the same sequence; the median apophysis and the conductor project from beneath the tegulum in the corresponding positions, and the elbowed structure, which in the unexpanded bulb appears to arise at the base of the bulb is here clearly seen to be the embolic subdivision of the bulb. The most remarkable differences are the lack of a prominent distal hæmatodocha and the fact that the radix (Fig. 19, *ra.*) and stipes (Fig. 19, *st.*) are each a complete cylinder, instead of merely forming one face of the wall of a segment of the apical division, as in *Aranea frondosa*. At the distal end of the stipes, between this part and the embolus and the terminal apophysis, there is a vestigial distal hæmatodocha (Fig. 18. *d. h.*).

In this species there is an apophysis which like the median apophysis is joined by a flexible articulation to the tegulum within the cuplike cavity formed by the distal margin of the tegulum (Fig. 17 and 19, *p. m. a.*); this may be termed the *paramedian apophysis*. As I have not found this apophysis in other palpi, I do not consider it a fundamental part.

THE PALPUS OF *ARANEA GIGAS*.—The preceding species, *Aranea circulata*, and several others, have been separated from *Aranea* by Pickard-Cambridge and placed in the resurrected genus *Eriophora* of Simon. The peculiar form of the genital bulb in *Aranea circulata* appears to sustain this separation. But in the palpus of *Aranea gigas* (Fig. 20 and 21) we find a form intermediate between the *arana* type and what may be termed the *eriphora* type.

In the unexpanded bulb of *Aranea gigas* (Fig. 20) the parts are twisted so as to render the basal hæmatodocha conspicuous

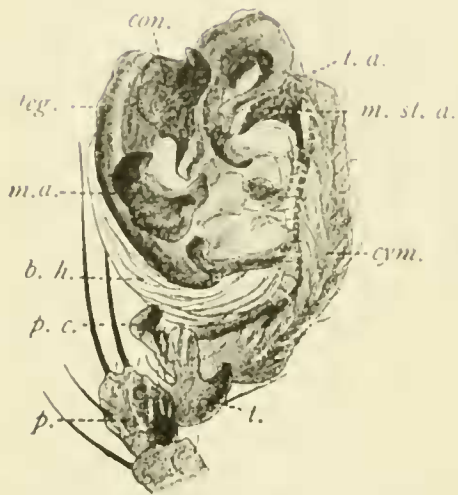


FIG. 20. Unexpanded bulb of *Aranea gigas*.



FIG. 21. Expanded bulb of *Aranea gigas*.



FIG. 22. Expanded bulb of *Dolomedes fontanns*.

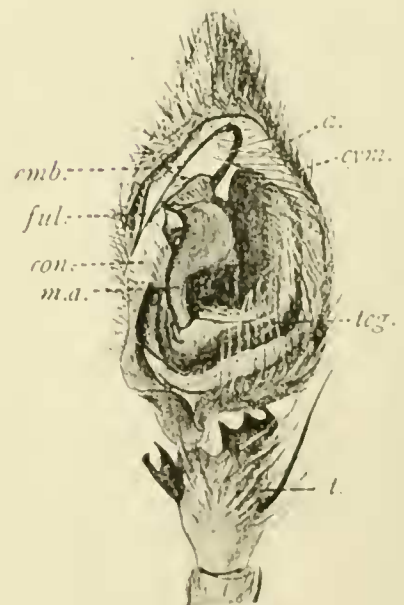


FIG. 23. Unexpanded bulb of *Dolomedes fontanns*.

as in *Aranca circulata*; but otherwise there is little similarity in appearance to either this species or to *Aranca frondosa*.

In the expanded bulb (Fig. 21) it can be seen that the embolic subdivision, is intermediate in form between the two types, resembling the aranea type in having a large distal hamatodocha and a well-developed median subterminal apophysis; and resembling the eriophora type in the form of the embolus, which is lamelliform (Fig. 21, 2). In the general view (Fig. 21) the embolus is covered by the tip of the stipes.

THE PISAURID TYPE OF PALPUS.—In the family Pisauridæ there is a type of palpus which, while it resembles the aranea type in its more general features, differs from that type in several important particulars. The palpus of *Dolomedes fontanus* (Fig. 22 and 23) may be taken as an example of this type.

A study of an expanded bulb of this species (Fig. 22) reveals the following characteristics: There is a well developed *petiole* of the bulb (Fig. 22, *pet.*), which, in this species, consists of two nodes with an unchitinized internode. The subtegulum bears very prominent *anelli* (Fig. 22, *an.*), which are described in a later paragraph. The *median apophysis* is prominent (Fig. 22, *m. a.*). The conductor (Fig. 22, *con.*) is extremely membranous. The *radix* and the *stipes* are not developed as distinct segments. The *embolus* is of the spiral type (Fig. 22, *emb.*) The *terminal apophysis* is modified into an organ for the support of the embolus (Fig. 22, *ful.*), which may be termed the *fulcrum* of the embolus. This type of terminal apophysis has been termed, incorrectly, the conductor. The true conductor in this species, as in all others studied, is an organ whose function is to protect the tip of the embolus in the unexpanded bulb. At the base of the terminal apophysis, at the point where the embolus arises, there is a lamelliform *lateral subterminal apophysis* (Fig. 22, *l. st. a.*).

In the unexpanded bulb (Fig. 23), the long *embolus* makes a curve in the distal end of the alveolus beyond the end of the bulb. The *fulcrum* is applied against the embolus on its concave side, and has a furrow on its distal face within which the embolus rests. The distal part of the *conductor* is wrapped about the tip of the combined embolus and fulcrum, serving, as in all other cases observed, as a protection to the tip of the embolus.

THE ANELLI OF THE SUBTEGULUM.—In *Aranca*, the chitinized part of the wall of the basal division of the bulb, the subtegulum, is reduced to a ringlike sclerite (Fig. 24, 1.); but in certain other genera, the subtegulum is cup-shaped or basket-like. In *Agelena navia* (Fig. 24, 2), one side of the subtegulum is greatly thickened; at the proximal end of this thickening, which corresponds to the lunate plate, there is a condyle, which articulates with the petiole; and at the distal end, there is a condyle, which articulates with the tegulum. The other side of the cuplike subtegulum contains in its wall several parallel, incompletely ringlike sclerites; these may be termed the *anelli* of the subtegulum. In *Dolomedes fontanus* (Fig. 24, 3), the anelli of the subtegulum are greatly thickened and form prominent projecting ridges.

It is probable that the presence of the anelli of the subtegulum, and their nature when present will afford characters of use for taxonomic purposes.



FIG. 24. Three kinds of subtegulum.

THE DIFFERENT TYPES OF EMBOLUS.—The form of the embolus varies greatly in different species of spiders. Two principal types can be recognized, the connate and the free; and the free type includes three subtypes.

The connate type of embolus.—In the connate type, the embolus is not separate from the middle division of the bulb but is merely a more slender continuation of it, as in the tarantulas, *Loxosceles* (Fig. 4), and *Ariadna*.

The free type of embolus.—In the free type of embolus, there are one or more movable articulations between the embolus and the middle division of the bulb. In the free type, the embolus varies greatly in form; but the different forms can be grouped under three heads: coniform, lamelliform, and spiral.

A coniform embolus.—In this type, there may be a broadly expanded base; but the projecting part of the embolus is a straight or slightly curved cone. The embolus of *Aranca frondosa* (Fig. 25, 1) is an example of this type.

A lamelliform embolus.—In this type the embolus is flattened, and may bear a greater or less number of apophyses; an example of this type is found in *Lepthyphantes minuta* (Fig. 25, 2.)

A spiral embolus.—In the spiral type, as seen in *Agelena*, for example, the embolus is long, slender and coiled; and, in a well-expanded specimen, it is seen to be composed of three distinct parts: first, the wall of the convex side is densely chitinized, forming a gutterlike sclerite, which may be termed the *trunk of the embolus (truncus)* (Fig. 25, 3, *t. e.*); second, the greater part of the wall of the embolus is membranous, and forms a loose flap along the concave side of the organ, which contains the ejaculatory duct; this flap (Fig. 25, 3, *p. p.*) may be designated the *pars pendula* of the embolus; third, at the distal end of the *pars pendula*, there is a triangular, chitinized area, through which the ejaculatory duct opens (Figs. 25, 3, *a. s.*), this may be termed the *apical sclerite* of the embolus.

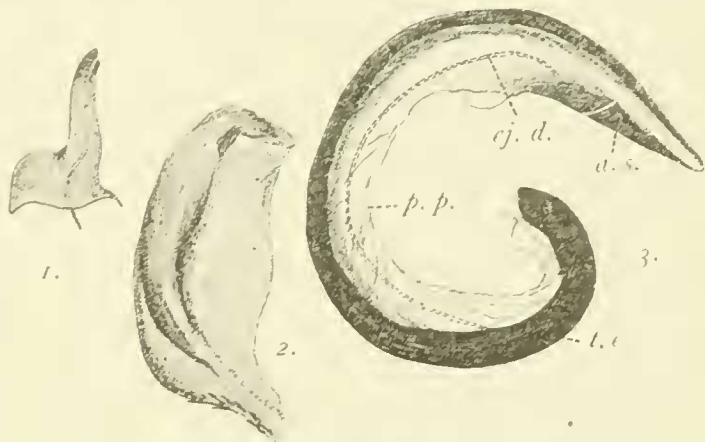


FIG. 25. Three types of embolus.

The *pars pendula* and the *apical sclerite* may be completely withdrawn into the trunk of the embolus, so that only the latter is visible; the embolus then appears to be merely a strongly chitinized style; it is in this condition that it is usually seen and described.

CONCLUSION.

In the preparation of this paper many palpi other than those figured here have been studied; and it is believed that the series examined has been sufficiently large to warrant the conclusions given regarding the fundamental parts of the genital bulb. There remains to be determined the manner in which the different types of palpi have been specialized in other families of the order, and the details of the modifications characteristic of genera. This, however, is too great an undertaking to be attempted at this time, and must be left for those who monograph the different families.

I wish, however, to urge the importance of describing palpi from expanded specimens. A large proportion of the figures of palpi that have been published, being of unexpanded examples show comparatively little of the structure of this organ. The labor involved in expanding the bulb of a palpus is very little; a preparation can be made in five minutes; and in no other way can so much be done to make possible a description that will describe.

The following tabular statement shows the relations of the fundamental parts of the tarsus in the more specialized types of palpi; not all of these parts are invariably present, and frequently subordinate apophyses are developed.

Body of the tarsus.

 Cymbium, containing the alveolus.

 Paracymbium.

Genital bulb:

 Internal parts.

 Receptaculum seminis.

 Fundus.

 Reservoir.

 Ejaculatory duct.

 External parts.

 Basal division of the bulb.

 Basal hæmatodocha.

 Petiole.

 Subtegulum.

 Lunate plate.

 Anelli of the subtegulum.

 Middle division of the bulb.

 Middle hæmatodocha.

 Tegulum.

 Median apophysis.

 Paramedian apophysis.

 Apical division of the bulb.

 Conductor.

 Embolic subdivision.

 Radix.

 Stipes.

 Embolus.

 Body of embolus.

 Pars pendula.

 Apical sclerite of the embolus.

 Distal hæmatodocha.

 Lateral subterminal apophysis.

 Mesal subterminal apophysis.

 Terminal apophysis, sometimes developed into a fulcrum.

In conclusion I wish to acknowledge the very efficient assistance in the preparation of this paper, of Miss Anna C. Stryke, who prepared the illustrations for it.

NAMES OF THE PARTS OF THE PALPUS AND ABBREVIATIONS USED
FOR THEM IN THE ILLUSTRATIONS.

Accessory branch=paracymbium.	Mesal subterminal apophysis, <i>m. st. a.</i>
Alveolus, <i>a.</i>	Middle division of the bulb, <i>m. d.</i>
Anelli of the subtegulum, <i>an.</i>	Middle hæmatodocha, <i>m. h.</i>
Apical sclerite of the bulb, <i>a. d.</i>	Paracymbium, <i>p. c.</i>
Apical sclerite of the embolus, <i>a. s.</i>	Paramedian apophysis, <i>p. m. a.</i>
Basal division of the bulb, <i>b. d.</i>	Pars pendula of the embolus, <i>p. p.</i>
Basal hæmatodocha, <i>b. h.</i>	Patella, <i>p.</i>
Clavis=median apophysis.	Petiole of the bulb, <i>pet.</i>
Conduetor of the embolus, <i>con.</i>	Radix, <i>ra.</i>
Coxa, <i>c.</i>	Receptaculum seminis, <i>r. s.</i>
Coxal spur, <i>c. s.</i>	Reservoir, <i>res.</i>
Cymbium, <i>cym.</i>	Scapus=median apophysis.
Distal hæmatodocha, <i>d. h.</i>	Spiral muscle=hæmatodocha.
Ejaculatory duct, <i>ej. d.</i>	Stripes, <i>st.</i>
Embelic subdivision of the bulb, <i>e. s.</i>	Style=embolus.
Embolus, <i>emb.</i>	Subtegulum, <i>s. teg.</i>
Femur, <i>f.</i>	Tegulum, <i>teg.</i>
Fulcrum, <i>ful.</i>	Terminal apophysis, <i>t. a.</i>
Fundus of the receptaculum seminis, <i>fu.</i>	Tibia, <i>t.</i>
Lateral subterminal apophysis, <i>l. st. a.</i>	Trochanter, <i>tr.</i>
Lunate plate=subtegulum in part.	Trunk of the embolus, <i>t. e.</i>
Median apophysis, <i>m. a.</i>	

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